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MODERN OPTICS AND THE MICROSCOPE.

The Microscope: its Construction and Management. Including Technique, Photomicrography, and the past and future of the Microscope. By Dr. Henri van Heurck, &c. English edition re-edited and augmented by the author from the fourth French edition, and translated by Wynne E. Baxter, F.R.M.S., F.G.S. (London: Crosby Lockwood and Son, 1893.)

THIS is a handsome, even a luxurious, book. It is beautifully printed on highly-finished paper, and with a margin ample enough to satisfy the most exacting connoisseur. The illustrations are clearly produced, the binding is admirable, and after a careful comparison with the last French edition, we do not hesitate to say that the translation is as felicitous as it is accurate.

Its author has aimed apparently at an elementary treatise on the microscope, which is nevertheless intended to cover almost the entire field involved in its history, production, and use. The difficulties of such a task are not a few. To be elementary and thoroughly popular up to a limit, very sharply defined, and then to lead on those who choose to follow into the deeper aspects of this many-sided subject, is at once practical and natural. The optics of the modern microscope are the possession of the specialist. Abbe himself has failed to make them accessible to and understanded by any but those educationally equipped. Hence the constant misunderstanding of the fundamental principles of the Diffraction Theory and its related applications so frequently manifest even where the subject is supposed to be more or less familiar.

As might have been readily supposed, the author of this treatise has given evidence of skill in the presentation of the main points of elementary optics; it is, however, clearness and conciseness, not originality, that is to be noticed. The illustrations are those familiar to English text-books for the last quarter of a century, and the diffraction theory has in no way been simplified to the reader of an elementary treatise by that most efficient of all elementary modes of imparting ideas on more or less abstruse subjects, viz. carefully devised and well-explained diagrams.

Considering the object of this treatise, viz. the impartation of knowledge to those not mathematically prepared to follow it in that direction, by giving a concise, clear, and comprehensive view of the meaning and application of the diffraction theory of microscopic vision, the transition from the first to the second chapter will be so abrupt and unlinked as to leave the elementary reader practically in the dark. The chapter on "The Theory of Microscopic Vision" is unexceptional so far as it goes. It cannot be other, it is Prof. Abbe's; but in a treatise claiming to maintain its elementary character more completely than any other similar work which covers so wide a range this is surely not enough.

The diffraction theory of vision is introduced to the tyro with no explanation of what diffraction is, and with no illustration of its action until he is plunged *in medias res* in Abbe's application of it to the profoundly important and inestimably valuable theory itself. The "elementary" character of this is at least questionable. Beyond this that most important factor in the diffraction theory in its practical application, Numerical Aperture, is wholly without explanation, save such as arises from its technical introduction and employment; but there are few points on which it is more important that an elementary student should be more clearly instructed, and there are few that lend themselves more to efficient diagrammatic presentation. In the same relation it may be noted that the very essential formula n sin u—expressing the general relation discovered by Abbe between the pencil of light admitted into the front of the objective, and that emerging from the back lens of the same, which is such that the ratio of the semi-diameter of the emergent pencil to the focal length of the objective could be expressed by the sine of half the angle of aperture (u) multiplied by the refractive index of the medium (n) in front of the objective or n sin. u—but this is a German mathematical formula; and its English equivalent is μ sin. ϕ, and although the German form of symbol is employed in England, and thoroughly understood by mathematicians, those who are entering for the first time upon a study of this difficult subject, and therefore unaccustomed to the mathematical formulæ employed, might readily fall into confusion, seeing that the "elementary" source of their information leaves them without a hint on the subject.

Another serious defect, as we believe, in this "elementary" presentation of the diffraction theory of microscopic vision is the absence of an easy explanation of the *photometrical* equivalent of different apertures. Certainly it is not of the essence of the problem, but it is just one of those points which in a very marked and instructive manner illustrate the meaning and value of numerical aperture as such; and for elementary exposition this must be of importance. Thus, if two circles be taken to represent the backs of two objectives of the same power but of different apertures, and the radius of one be twice that of the other, then each radius will represent the angle n sin. u. But because the areas of these circles are to each other in the proportion of the squares of their radii, it follows that if each radius be designated by n sin. u, the area of the lesser circle will be to the area of the greater circle as the square of the radius of the former is to the square of the radius of the latter. Hence the area of the greater circle will be four times as great as that of the lesser, which teaches that since the numerical aperture of one objective is twice as great as that of another its illuminating power will be *four times* as great—a most important incidental and explanatory *raison d'être* for great N. A.

In this connection we notice what is certainly not easily explicable as an exposition of the details of Abbe's great theory. On page 56 of "The Microscope" Dr. Van Heurck almost incidentally states the very important fact that "Prof. Abbe has satisfactorily established the fact that a certain relation must exist between magnification and angular (?) aperture." This is undoubtedly one of the most important demonstrations of the theory. Great numerical apertures have proved of untold value to the competent student of minute details, by opening up structures that mere amplification must have left for ever impenetrable. But that does not annul the import-

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ance of small apertures. Low amplifications are as useful in their own department as high ones; and to put great apertures to lower magnifying powers than such magnifying power warrants is to sin against the elementary principles of the Abbe theory of vision. And on the other hand, wide apertures can never be utilised unless there is a concurrent and suitable linear amplification of the image which is competent to exhibit to the eye the smallest dimensions which are by optical law within the reach of such apertures.

Thus it follows that great amplification will be useless with small apertures. If the power be deficient the aperture will not avail; if the aperture be wanting nothing is gained by high power. The law is, "Employ the full aperture suitable to the power used." In Abbe's words, "A proper economy of aperture is of equal importance with economy of power."[1]

Taking these facts, then, which are apparently recognised by Dr. Van Heurck, it is very remarkable to find on page 49, in a discussion of the "screw threads" or gauges employed by the makers of microscopes, that the general value of the English gauge is admitted, but it is added, "The English thread is not, however, all that we have to say on this matter. In America the *American thread* is also employed, which is considerably greater, and admits the use of lenses with a much larger diameter, *and thus offers certain advantages*. In the first place, the larger the lens the easier it is to make, and consequently the real curvatures approach closer to the calculated curvatures; then the larger the lens the more luminous rays it admits, and this in photography is not to be despised."

To our judgment this statement is a contradiction of the admission made on page 49, quoted above.

The enlargement of the screw for the purpose of putting in larger back lenses to objective combinations was first mooted in America in 1879,[2] when "Mr. Bullock urged the desirability of adopting a uniform objective screw of larger size than the Society screw now in use (1879), as being essential to the efficacy of *low power lenses of high angle*."

This "American gauge" was subsequently introduced and known as the "Butterfield gauge of screw for objectives."[3]

Now, we must remember the date of the introduction of this large gauge for objectives, and its relation to the introduction of the apochromatic system of lenses. We must further remember that the purpose of its adoption was to permit the introduction of larger back lenses than the Society gauge would suffer into an objective combination. This meant giving relatively great apertures to lower powers. But this, carried beyond a certain limit, violated a fundamental law of Abbe's theory.[4] Now it is said that these larger lenses are easier to make (!) and approach more nearly to the calculated curves. But in truth objectives with wide apertures which are low powers, and must therefore have large backs, are most difficult lenses to produce. It was, in fact, to escape the difficulty of giving lower powers larger angles that opticians of the first rank always designated their objectives as of lower magnifying power than they really were. They in fact made a $\frac{2}{3}$rds a $\frac{1}{2}$; a $\frac{1}{2}$ a $\frac{4}{10}$ths; a $\frac{4}{10}$ths a $\frac{1}{4}$; a $\frac{1}{4}$ a $\frac{1}{5}$; and so on.

Since Butterfield's gauge was introduced, long before the days of apochromatism, that is when our ignorance allowed us to over-aperture our low magnifying powers, it was tolerable, because it was evidence of experimental effort to improve the capacity of our lenses. But to-day *with* the society screw we are easily provided with a series beginning with a 1 inch objective of ·3, and a $\frac{1}{2}$ inch objective of ·65 N.A., and we may venture to think that these are the highest ratios of aperture to power that will be accomplished for many a day; and therefore the highest ratios allowable by the Abbe theory of vision, which we now know, at least in this point, to be an enunciation of the established laws of optics.

Moreover, *these* lenses are really difficult to make, with their back lenses easily placed within the diameter of the Society screw. A high ratio of aperture to power always involves great expense in production; and therefore we find that the *low-priced* oil immersions of this immediate time are $\frac{1}{12}$ths and $\frac{1}{8}$ths, not objectives of low magnifying power, and for this reason only.

Since then the Society screw is sufficient for more than double the apertures shown by Abbe to be in suitable ratio to the lower powers, we find it more than difficult to account for the teaching in a treatise intended to be essentially elementary, that the Butterfield screw gauge for objectives provides conditions which "offer certain advantages," when the supreme object of this part of the book is to enunciate fully the nature and qualities of oil immersion achromatic, and especially apochromatic, object glasses, by which we can get larger apertures with the society screw than in the old days of Butterfield's gauge could be got by the use of abnormal backs to objectives. We find also that "penetrating power" is referred to in passing as one of the properties of object glasses (p. 56); but since the diffraction theory of microscopic vision is associated with a special interpretation of what this means, and since it is to Prof. Abbe that we are indebted for placing this hitherto obscure matter on a sound, scientific basis, it somewhat disappoints the reader to find no allusion whatever to the valuable work done on this subject, nor any elementary endeavour to explain the great truth that the actual depth of vision must always be the exact sum of the accommodation depth of the eye and the focal depth of the objective. But there are few matters of more practical importance or that lend themselves more to simple exposition.

In a treatise purporting to be essentially for the beginner we confess to disappointment concerning the instructions as to the "choice of a microscope." What is needed is that the tyro should know the *essentials* of the instrument; the points in it that are of indispensable importance, and a clear account of the manner in which these may—by the uninitiated—be seen to be of inferior or acceptable workmanship. The reader is not even informed that in so important a matter as the *fine adjustment* there is a different value to be attached to several entirely different methods by which this function of the microscope is performed. The bar and lever movement, essentially the best in principle and practice, is only referred to as existing, in the index, which is thus made to serve as a kind of glossary; and even more remarkable is the fact that the patent lever fine adjustment of Swift and Son, the only fine adjustment which, in our judgment, makes the "Jackson Model" microscope (which Dr. Van Heurck evidently affects) at all a practicable instrument, is treated in the same way. So indeed is Campbell's differential screw; and the highest commendation is given to the form adopted in the author's own model. No doubt in its present form it is relieved of many defects incident to the form of fine adjustment to which it belongs; but it must be remembered that we are told that each of the divisions of the milled head of this fine adjustment corresponds to the $\frac{1}{1300}$th of a millimetre. Yet the screw which gives this fine result has to lift the whole "body" of the instrument. In the lever fine adjustments only a nose-piece is lifted, having an inconsiderable weight, and producing in practice no friction, and to this the objective is attached; it certainly appears but reasonable, as it has proved in practice to workers who have employed the several methods for continuous years, that the "wear and tear" upon so fine a screw to which such heavy work is given does not contribute to permanent steadiness, or in constant work, to continued accuracy.

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[1] J. R. M. S., ser. ii. vol. ii. p. 304.

[2] *American Naturalist*, vol. xiii. p. 60.

[3] J. R. M. S., ser. ii. vol i. p. 301.

[4] *Ibid.*, vol. ii. p. 204.

In fact, after careful study of the microscope specialised in this treatise, it is difficult to discover anything really new or distinctive in it save the bringing of the fine adjustment pinion of the sub-stage above the level of the principal stage. The value of this may be variously assessed, but it has the plain disadvantage of preventing the complete rotation of the principal stage; and it may be doubted if it has any advantage which will compensate for this.

There is little, if anything, to enable the reader to distinguish as to the practical value of one form of stand as compared with another, and yet there can be no greater divergence in form than that between the Continental stand on the one hand with its dead weight to produce steadiness, and the two English models known as the Ross and Jackson models respectively on the other. What distinguishes them, in what either of them has superiority over the other, and wherein in any of them what is essential to a first-rate working microscope, is nowhere discussed.

It is true that the models of many makers are presented and beautifully printed; but many of these are not printed in these pages as revealing essential differences important for the reader to observe, but they are placed amongst others simply as the productions, with slight variations, of the same instruments by different makers. We cannot but believe that if some plain directions had been given as to the essentials of a good microscope, and the principal models passed in review showing their conformity or otherwise to these requirements, the "elementary" object of the book would have been more fully accomplished, and the tyro more fully aided in the "choice of a microscope."

Dr. Van Heurck has shown his practical knowledge of the microscope as a manipulator in many ways, in this book, but perhaps this is nowhere more fully seen than in his full appreciation of the *condenser* as an indispensable instrument in bringing out the finest optical possibilities of the most perfectly constructed object glasses. His book may be said to be alone amongst continental treatises on the microscope in this respect. It has been by very tardy steps that the continental makers, or the continental microscopists, have learned to appreciate the immense importance of a condenser in causing optical combinations to give their highest results. It is but recently that so leading a firm as Zeiss has yielded on this point and produced condensers. The first was chromatic, and, as a consequence, proportionately unsatisfactory. Then came the most useful achromatic form of Abbe. But we are glad to observe that Van Heurck recognises that the *apochromatic* immersion condenser of Powell "is the most perfect condenser which exists at present" (p. 85). It is inevitable that with apochromatic objectives it should be. We cannot possibly see how the splendid objectives on apochromatic principles can give their finest results unless they are illuminated by an apparatus which is not only as perfect in workmanship, but of as great a numerical aperture, and with as complete corrections as the objective which is collecting the light and forming the image of the object the condenser is illuminating.

And for this reason, while we admit fully that the plate of photo-micrographs produced in this and other volumes by the very exceptional skill of Dr. Van Heurck with the most remarkable object glass which the manipulative skill of man has yet produced, viz. the 2·5 mm. with N.A. 1·63, is a monument to his manipulative ability, we still contend that he worked under difficulties of no small importance. The only condenser provided for this lens by the great firm which produce it, is one which of necessity has a flint front, but is as wholly uncorrected as the glasses used by Hooke or Bonanni!

Now if it be important to use an apochromatic condenser at all, how much more important to use it on such a lens, with such an aperture and such exquisitely refined corrections. This objective has never yet had its best power revealed, because its illumination has been always a counteraction of its own refinements.

We are surprised that in manipulation the tyro is recommended in this treatise to focus *down* upon the object first, of course with great care, and then to find the actual focal point by withdrawing the tube by either coarse or fine adjustment. A far more elegant and safe method is certainly adopted, and we doubt the preference expressed for daylight as the best constant source of illumination. It is uncertain and always variable and more refractory than the edge of a good lamp-flame, unless we need a monochromatic ray from a sunbeam.

At the close of the book there is a communication which had appeared before in the Journ. Roy. Micro. Soc., from Dr. S. Czapski, which gives a suggestion for the possible enlargement of the practical N.A. of homogeneous object-glasses, which makes an advance to 2·0 possible without the employment of the dense flint and highly refractive media needed by the lens spoken of above. In fact it is plain that true monochromatic light may increase a N.A. of 1·40 to 1·75.

There is a chapter on photomicrography which has the value that is inevitable, coming as it does from one of the most practised and efficient workers; still it can hardly be expected to be exhaustive, and every practical photomicrographer has, and adopts as most perfect, his own methods; and as none will ever become photomicrographers who have not some ingenuity and enthusiasm, it is only needful that they be set to work, and they will undoubtedly find *their own* "best methods."

This treatise is too general to expect from it more than useful and suggestive hints on the subject of the preparation and mounting of objects; and the same may be said as to the history of the microscope, which is nevertheless given in an interesting and useful manner. The book will undoubtedly attract many readers, and it will afford help to many who are seeking it; but we respectfully doubt whether it will enable the elementary reader to fully follow the diffraction theory of microscopic vision, so as to be able to understand its application to the wide range of subjects supposed to be dealt with from that point of view by this sumptuous treatise.

W. H. DALLINGER.

A UNIVERSITY EXTENSION MANUAL.

The Earth's History: an Introduction to Modern Geology. By R. D. Roberts, M.A. (Camb.), D.Sc. (Lond.). With Coloured Maps and Illustrations. (London: John Murray, 1893.)

THIS is not a large book, and a slightly less ambitious title might have been more appropriate. Certainly it is an introduction to the study of modern geology rather than a history of the earth, for the latter is regarded from a limited point of view. But from the page preceding the frontispiece it appears that the volume is one of a series of "University Extension Manuals." It partakes, therefore, of the advantages and disadvantages of this method of disseminating knowledge.

The topics treated by Dr. Roberts are the progress of geological thought: the beginnings of the earth's history: the modifications of its surface due to forces destructive and reproductive: the movements of its crust, including the action of volcanoes. Finally he deals with the formation of rock masses, and attempts to give—though of necessity this subject is very imperfectly treated—some idea of the evolution of the British Islands.

The materials employed by the author are not generally novel, for one text-book must draw from much the same storehouse as another, but Dr. Roberts has a lucid and pleasant method of statement, gained no doubt by his experience in the lecture room. One point, however, though it relates to a well-worn subject, will be fresh to most readers. In speaking of the submergence of the so-called Temple of Serapis at Puzzuoli, Dr. Roberts cites a passage from the Acts of Peter and Paul, an apocryphal booklet, to which attention was drawn a few months since by Mr. Thomson (*Geol. Mag.*, 1892, p. 282). This states that Pontioli (Puteoli, now Puzzuoli) was submerged as a punishment for the martyrdom of Dioscurus. "They all see that city Pontioli sunk into the sea-shore about one fathom, and there it is unto this day for a remembrance under the sea." On which passage Dr. Roberts observes that when the Acts was written, "Puzzuoli was under water, and had been so for so long a time that the memory of the actual events had been lost and replaced by the tradition recorded in the Acts." At first sight this, as he says, seems in favour of the submergence having occurred "between the third and fifth centuries, and probably earlier than the fourth."

This passage certainly makes it probable that the submergence began at a rather early time, but it is no easy matter to fix the date of any passage in these Acts. Parts of the book are believed to be as old as the second century, while others are not earlier than the fifth century. The book, also, was not of Western but of Eastern origin. Had the book been written in Italy then, notwithstanding its other absurdities, some weight might be attached to a topographical reference; but these, as it was compiled at a distance, and by obviously ignorant people, seriously impair its credit. It is also needful to show that this story forms part of the later recensions and is not merely founded on some vague tradition of change of level in the neighbourhood. In any case, Dr. Roberts seems to go a little too far in saying "this would allow about ten centuries, during which the marble columns were under water exposed to the action of the living molluscs." Hardly so; this tradition at most would not take us beyond the first submergence, that indicated by the brackish water deposit at the base of the pillars. Over this came an irregular mass of volcanic ash, which was covered by a calcareous tufa, in places full four feet thick. The former, of course, may have accumulated in a few hours, but the latter must indicate a considerable time. The temple, also, must have been in complete ruin before the showers of ashes fell—which also would require time. So that Dr. Roberts perhaps would have done better to have adhered to the more cautious statement in Mr. Thomson's letter, and not claimed quite so long a period for the maximum submergence.

Within the limits, which the necessities of the case impose, the book is well conceived and well executed: though we cannot help doubting the wisdom of encouraging, by manuals necessarily partial and incomplete, students to imagine that they have really mastered a subject; at any rate, it should be frankly admitted that this, however useful and interesting, is not education.

OUR BOOK SHELF.

The Health Officer's Pocket-Book. By E. F. Willoughby, M.D., D.P.H. (London: Crosby Lockwood and Son, 1893.)

THIS is a work the object of which is to provide a portable and well-bound book of reference, to which the health officer may turn at any moment for most of the facts, formulæ, and data required in his daily practice; and while one cannot give unqualified assent to Dr. Willoughby's contention that such a book is indispensable, one is prepared to acknowledge that it may prove to be useful. It is not easy, however, to conceive the conditions under which a health officer is called upon to take action or to give advice, at a moment's notice, upon points so remote from the routine practice of his duties that he will ever find it necessary to carry about, for consultation, a pocket-book of abstruse sanitary facts and formulæ and legal enactments. If such a work is indispensable, the author would have done well to restrict its bulkiness somewhat, and more especially since he could have achieved this by the omission of a great deal of matter which is, on the face of it, foreign to the purpose of the book. To instance such:—The parts which nitrogenous and non-nitrogenous food stuffs play in the animal economy; the origin and nature of cyclones; a quantity